AD-A037 541 WESTON OBSERVATORY MASS F/G 8/14

INVESTIGATION OF MAGNETIC FIELD PHENOMENA IN THE IONOSPHERE.(U)

SEP 76 J F DEVANE, R DALRYMPLE, E JOHNSON F19628-74-C-0003

UNCLASSIFIED AFGL-TR-76-0230 NL

1 OF 1

AD

A037541

END

DATE FILMED

4-77

ADA037541

AFGL-TR-76-0230

(12)

INVESTIGATION OF MAGNETIC FIELD PHENOMENA IN THE IONOSPHERE

Rev. John F. Devane, S.J.
E. Johnson
R. Dalrymple

September 1976

Boston College
Chestnut Hill, Massachusetts 02167

Final report
1 August 1973 - 30 June 1976

Approved for public release; distribution unlimited.

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

 (9) Final rept. 1 Aug 73-30 Jun 76,

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (19)
(18) AFGL-TR-76-0230

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
(6) Investigation of Magnetic Field Phenomena in the Ionosphere.

5. TYPE OF REPORT & PERIOD COVERED
Final Report
Aug. 1, 1973- June 30, 1976

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) John F./Devane, [redacted] Edward E./Johnson
~~and~~ Robert R./Dalrymple

8. CONTRACT OR GRANT NUMBER(s)
(15) F19628-74-C-0003

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Rev John F. Devane, S.J.
Weston Observatory
Boston Collge , Weston, MA 02193

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
62101F
76010901

11. CONTROLLING OFFICE NAME AND ADDRESS
Air Force Geophysics Laboratory
Hanscom AFB Massachusetts 01731
Monitor/ R.O. Hutchinson/PHG

12. REPORT DATE (11)
Sep ~~tember~~ 1976

13. NUMBER OF PAGES
34 (12) 36p.

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(16) 7601
(17) 09

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Geomagnetic observatory, Micropulsations, Geomagnetic instrumentation, Magnetometer network, Magnetic field variations, Fluxgate magnetometers, Searchcoil magnetometers.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
Weston Observatory (Boston College) has maintained a geomagnetic observatory to continuously monitor changes in the geomagnetic field and to provide standards for magnetic instrumentation as well as a coil system in which a wide variety of magnetic instrumentation has been tested and calibrated to support AFGL testing and installation of portions of a magnetometer network for the collection and digital transmission of magnetic activity data to Bedford, Mass. The observatories are at approximately 55 deg N corrected next page

376835 B

cont.

20. geomagnetic latitude on sites from Massachusetts to the State of Washington. There are detailed engineering drawings of the sites, the instrumentation shelters and the instrumentation vans. Some problems with the instrumentation and their solutions are described.

Table of Contents Page

List of Tables

Page

List of Figures

1. Introduction

The subject contract is one in a series of contracts between Weston Observatory (Boston College) and AFGL (formerly AFCRL) dating back to 1957. These previous contracts are listed in Table 1. Over the course of the years, geomagnetic instrumentation has been constructed and maintained on the grounds of Weston Observatory, Weston, Mass. The entire facility has been developed to support Air Force programs investigating the magnetic environment of the Earth. A principal tool of investigation has been instrument packages consisting of magnetometers. particle counters and telemetry carried into the ionosphere by sounding rockets. The instrument packages were assembled and tested at Weston Observatory. The resultant data have been analyzed by AFGL personnel.

While the continued support of a rocket sounding program was a line item of this contract, the entire emphasis of the Air Force program shifted to a broader investigation of the magnetosphere and hence to the investigation of a different mode of geomagnetic activity, micropulsations. The major portion of the contractual effort then became the design, construction, installation, calibration and maintenance of portions of a network of stations for sensing geomagnetic activity and transmitting results digitally to the data acquisition station at AFGL, Bedford, Mass. In addition to investigations internal to the Air Force, the data from the network will be made available to the international scientific community and will be a major contribution on the part of the United States to the three year International Magnetosphere Study (IMS). The IMS is described by Lanzerotti et al[1].

---

[1]Lanzerotti, L.J., R.D. Regan, M. Sigiura, D.J. Williams, 1976, Magnetometer Networks During the International Magnetospheric Study, EØS, T.A.G.U., 57, 6.

Previous Contracts

AF19 (604) 3504	April 1, 1957 - March 31, 1959
AF19 (604) 5569	April 1, 1959 - Sept. 30, 1961
AF19 (628) 236	Oct. 1, 1961 - Oct. 31, 1964
AF19 (628) 4793	Nov. 1, 1964 - Oct. 31, 1967
F19 (628)-68-C-0094	Nov. 1, 1967 - Oct. 31, 1970
F19 (628)-68-C-0100	Nov. 1, 1967 - Oct. 31, 1970
F19 (628)-71-C-0083	Nov. 1, 1970 - July 31, 1973

TABLE I

As has often been the case in the past, major components of the system have been separately procured by the Air Force under other contracts. The various components were delivered to Weston Observatory to be integrated into a working system. Robert O. Hutchinson, PHG, has worked closely with the contract personnel on all phases of the project from initial site investigation to final installation.

2. The Geomagnetic Observatory

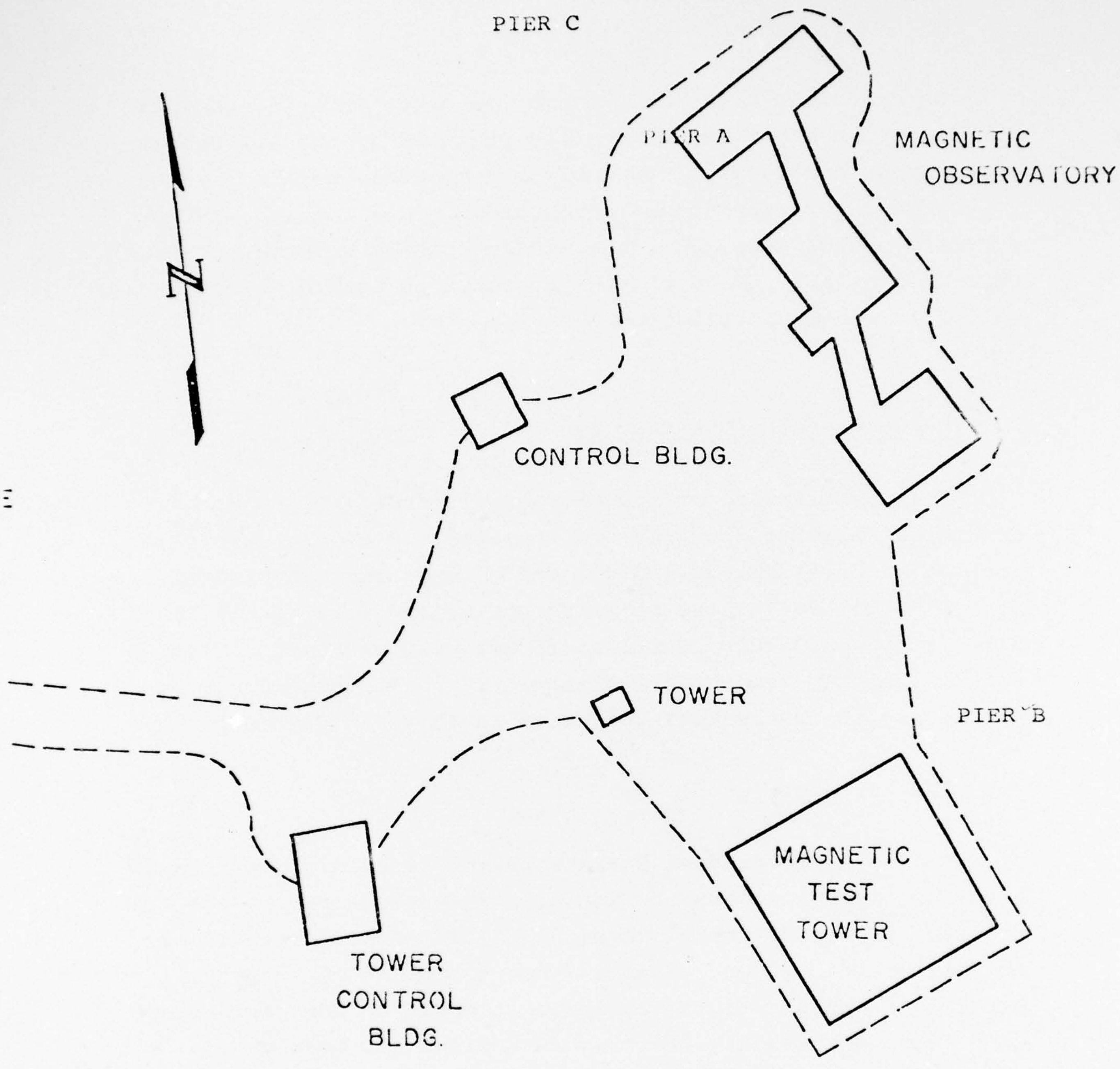
The installation of the geomagnetic observatory has been described in detail in previous reports[1]. The observatory is located at 42.385°N, 71.320°W. The geomagnetic coordinates are 53.900°N, 357.080°E. At an elevation of 190 feet (58 m), the site is approximately 15 miles (24 km) west of Boston, Mass. and is the only geomagnetic observatory in Northeastern U.S. A plan map of observatory buildings is shown in Figure 1.

2.1 The Variometers

Two sets of standard Ruska variometers of different sensitivities, measuring the horizontal and vertical components and the declination of the geomagnetic field, record continuously on photographic paper. Once a month a current of three milliamperes is applied to the calibration coils of the variometers to determine the scale factors. A typical calibration is shown in Table 2. The scale factors have remained essentially constant since the variometers were realigned in January 1973. A sample magnetogram is shown in Figure 2. The baseline values are determined by using another instrument to measure the actual component values at a given time. Available to do this are a

---

[1] Final Report, AF19(604) 3504, 1960.
Final Report, AF19(604) 5569, 1961.



PLAN MAP
WESTON OBSERVATORY
SCALE 1" = 20'

FIGURE 1

Calibration of Variometers

Date March 5, 1976

Time 15:40 - 15:50

Current 3 ma. Coil Constant 23.93 gammas/ma.

		high	low
H.	deflection (peak to peak) mm	48	30
	scale factor (gammas/mm)	3.0	4.8
	baseline (gammas)	17965	17835
D.	deflection (peak to peak) mm	25.2	21.6
	scale factor (gammas/mm)	5.7	6.8
	baseline (degrees W)	15.2	15.1
Z	deflection (peak to peak) mm	no trace	no current
	scale factor (gammas/mm)		
	baseline (gammas)		

TABLE II

Figure 2

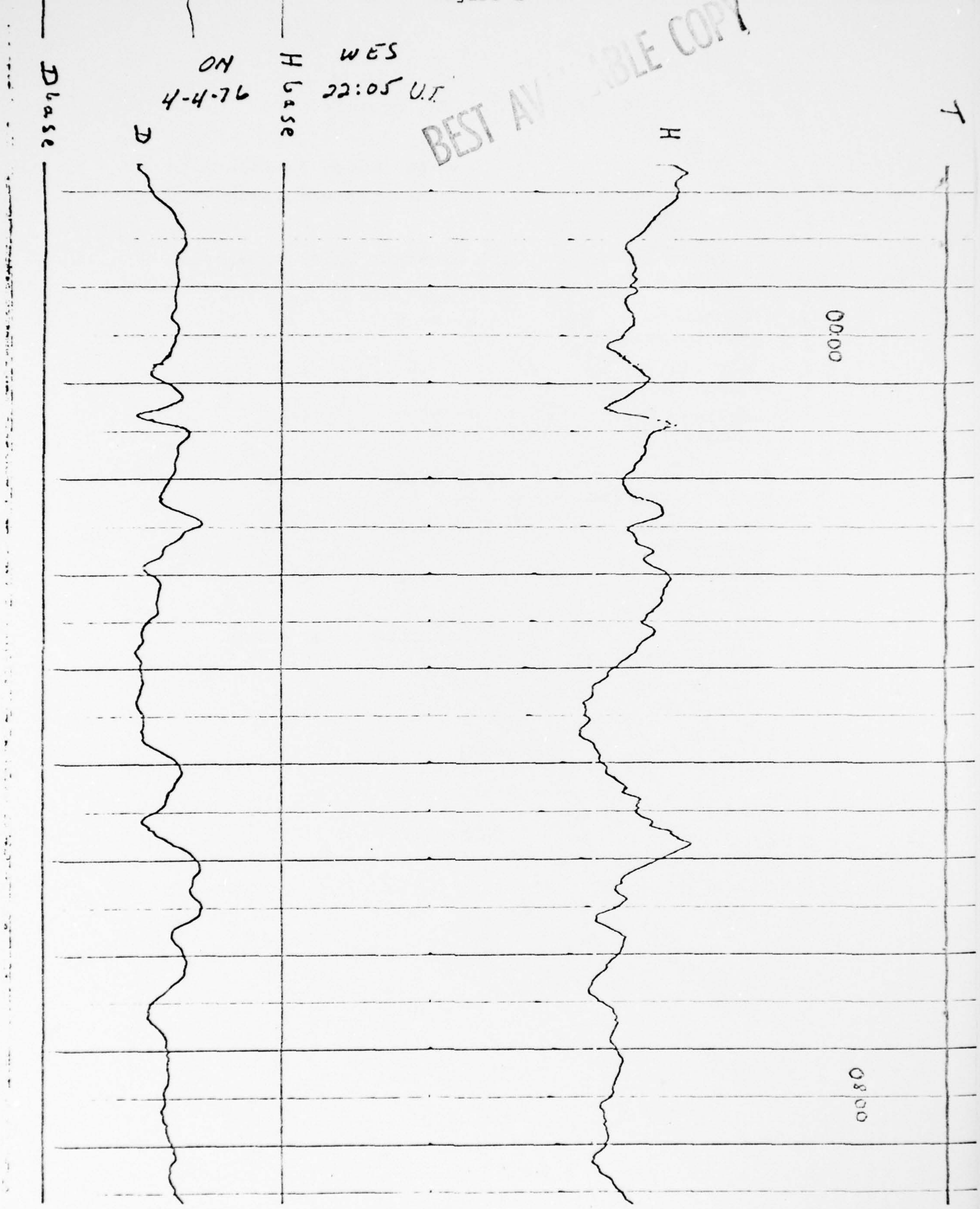
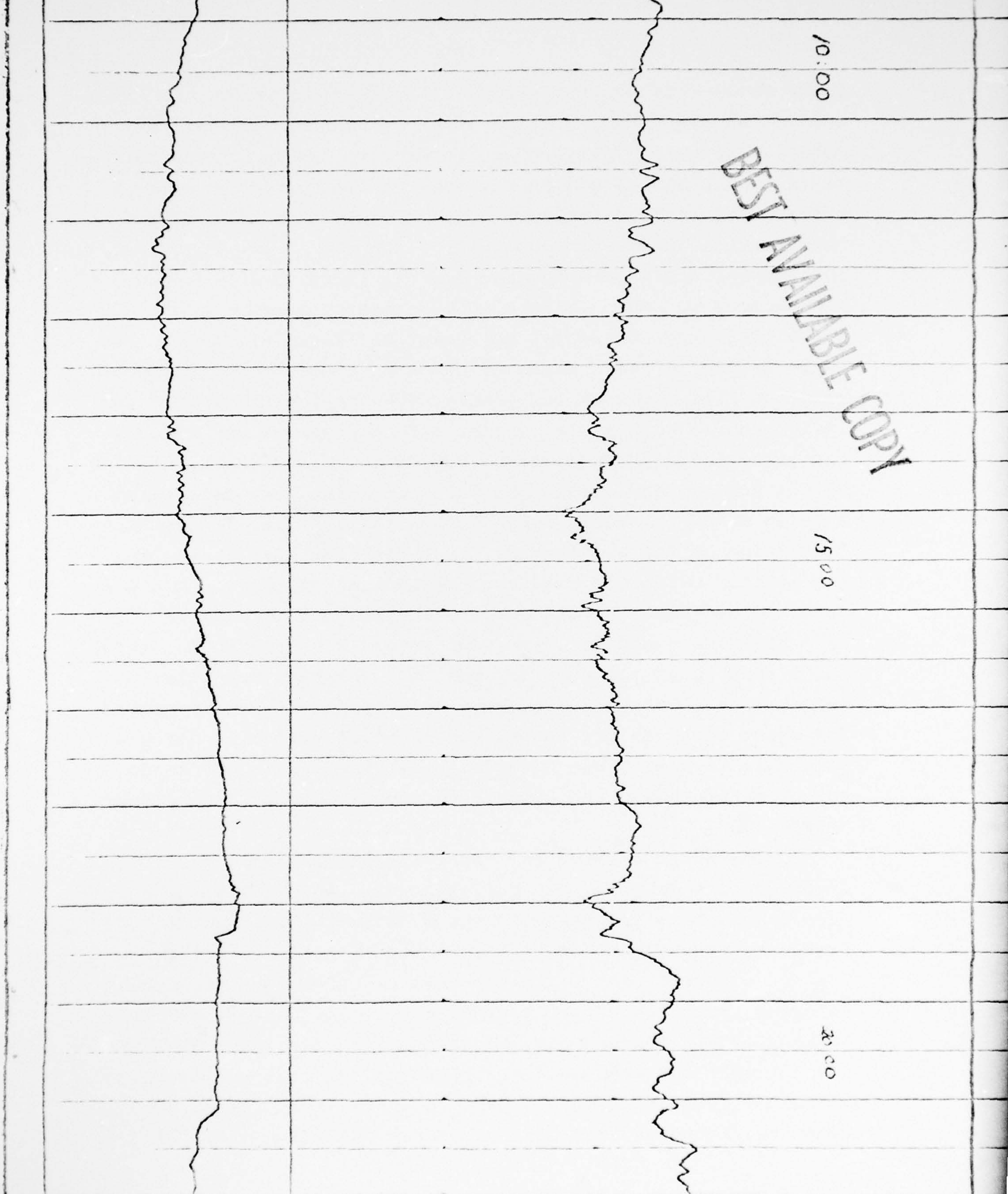


Figure 2



Ruska theodolite which measures both the declination and the horizontal component, a Ruska observatory inclinometer, an Askania Universal Torsion magnetometer to determine the horizontal and vertical components and, on loan from the U.S.G.S. observatory at Fredricksburg, Va., a quartz horizontal torsion magnetometer (QHM). Through use of the QHM it has been possible to transfer standards from the Fredricksburg, Va. Geomagnetic Observatory to Weston. In a long series of measurements during April 1975, the horizontal component on Pier A was determined to be 18,220 gammas. Since at the same time the total field value on Pier A was 57,131 gammas, the vertical component was 54,147 gammas. These, of course, are average values because the magnetic field is continuously changing and representative of the time of day (17-18 hours UT) at which they were taken. A value which is stable over some period of time, is the baseline value of the variometers. But they too must change when the secular variation requires realignment of the variometers so that the traces be suitably recorded.

With one exception, the variometers have operated continuously throughout the contract period. The high sensitivity vertical variometer has resisted all efforts at realignment. The exact cause is not known, but it seems probable that the balancing mechanism has been damaged. The instrument is no longer manufactured and efforts to repair it have been unsuccessful.

Geomagnetic observatory data were published in AFCRL's Geophysical and Space Data Bulletin when it existed. The entire data set is available to the international scientific community because in June 1976, William Paulishak, director of the World Data Center A for Solar-Terrestrial Physics, Boulder, Colorado, microfilmed the variometer records dating back to January 1960. Through him, we have had in the past year, numerous requests for copies of our records. He took the opportunity to film all the records and make an arrangement whereby we will send the records to him on a quarterly basis for microfilming.

2.2 Total Field Magnetometer

Weston Observatory has had in operation almost continuously since 1957, a total field magnetometer. A very early model of the Varian Associates proton precession magnetometer was the first instrument used. The physical location of the magnetometer was often changed and from the sparse records of the locations, it is nearly impossible to reconstruct a history of the total field variation at the observatory. From January 1965 to April 15, 1973, a Rubidium vapor, total field magnetometer operated at one location, Pier C, Figure 1. A record of its output is published in the Geophysics and Space Data Bulletin and is on file at World Data Center A, Boulder, Colorado. In April 1973, this aging sensor failed totally. Experimentation with a dual cell cesium sensor began shortly thereafter, but it was not until November 1973 that consistent records were obtained and these from a new location, Pier B, Figure 1. In August 1975, during a period of very high temperature and humidity, this sensor failed. It was returned to the manufacturer, Varian Associates, for repair. During a period of very low temperature in December 1975, the replacement Cesium magnetometer failed due to a problem in the heater circuit. It was replaced by the repaired magnetometer, but that failed again during a cold spell, in February 1976 and was replaced by a Rubidium magnetometer. The Cesium magnetometers have been repaired. The Rubidium magnetometer is still in use.

The total field magnetometer is recorded on a stripchart and on a printed log. The stripchart records continuously at a speed of six inches per hour. On the printed log the Larmor precession frequency is recorded at 10 minute intervals. During a magnetic storm, the stripchart is extremely difficult to read because of rapid scale changes. As an aid in following the stormtime changes, a gate was set on the frequency counter so that if the frequency varies beyond the preset limits, the printer will be activated every minute. During March and April

1976, we acquired extremely detailed recordings of two very large magnetic storms which were accompanied by visable aurorae. The depression during the April storm, -900 gammas, was the largest storm for which we have an accurate record.

To insure continuous operation of the total field magnetometer during electrical power failures, which are not infrequent, a standby system was designed and constructed. When the electrical power cuts out, a bank of storage batteries supplies, through an inverter, power to the magnetometer, clock and the recorders. This has proved time and again to be a completely reliable system. Once the electrical power is restored, the batteries are cut out. The changeover time is about two seconds.

An attempt to reconstruct the recent history of the total field variation at Weston has led only to frustration. In January 1973 the monthly mean value of the total field was 57305 gammas from a Rubidium sensor on Pier C. In June 1976 the monthly mean value was 56975 from a Cesium sensor on Pier B. According to notes in the bulletin for the third quarter of 1973[1] the change in location of sensor produced a decrease in the monthly mean value of 110 gammas. But note 4 in the bulletin for the fourth quarter of 1973[2] states that the measured difference between Pier C and Pier B is about 42 gammas. The former value is closer to reality. Pier C is not accessible now.

We can demonstrate changes in total field values due to type of sensor. By simultaneously using two portable proton precession magnetometers the difference between Pier A and Pier B was determined to be 85 gammas. The difference between a proton sensor on Pier A and a Cesium sensor on Pier B was 86 gammas. Later the difference between a proton sensor on Pier A and a Rubidium sensor on Pier B was 94 gammas. Pier differences thus seem to depend on the type of instrument but

---

[1]Geophysics and Space Data Bulletin, AFCRL, vol. X, 3, 1973.

[2]Geophysics and Space Data Bulletin, AFCRL, vol. X, 4, 1973.

may also be due to slight differences in the positioning of the sensors since there is a small gradient across both piers. A change in Cesium sensors on May 20, 1974 led to a decrease of 10 gammas. Thus the decrease in the magnitude of the total field is due for the most part to changes in sensor type and in the location of the sensor. But all of the change cannot be attributed to these factors. A decrease in the magnitude of the dipole component of the magnetic field is very evident in the coefficients of the dipole term of the IGRF for 1965 compared with the same terms of the 1975 IGRF (Table 3). The predicted rate of change for the 1965 IGRF was almost 18 gammas a year, but the 1975 IGRF predicts a change of nearly 30 gammas a year.

This secular change implies a change in the baseline value of the total field magnitude. But what is a baseline for a total field magnetometer? The question has no ready answer. The proton precession (or a Cesium or a Rubidium) magnetometer measures the instantaneous magnitude of the total field vector. That magnitude is a continuously changing function of the local time of day, the month of the year, the configuration of and the charged particle population of the magnetosphere and the velocity and particle number of the solar wind. At the magnetic latitude of Weston (54°N) the value at local midnight, should, on very quiet days, be the least perturbed value[1]. Even though we have previously reported on the quiet day total field variation at Weston and its non-conformity with the international quiet days, a monthly average of the local, quiet day, magnetic midnight values should be an adequate baseline for the magnitude of the total field vector. We plan to compare, each month, the present Rubidium sensor on Pier B with a proton sensor on Pier A. From plots of pier differences and magnetic midnight values we

---

[1] Matsushita, S., and W.H. Campbell, Eds., Physics of Geomagnetic Phenomena, Academic Press, pp. 321-323, 1967.

[2] Final Report, AF19(628) 236, AFCRL-64-966, 1964.

Dipole Component

	IGRF 1965[1]	IGRF 1975[2]	
g	-30339	-30186	
g	- 2132	- 2036	
h	5758	5753	
total	30954	30653	gammas

Rate of Change of Dipole Component

$\dot{g}$	15.3	25.6	
$\dot{g}$	8.7	10.0	
$\dot{h}$	-2.3	-10.2	
total	17.75	29.32	gammas/year

TABLE III

[1] Knecht, D.J. The Geomagnetic Field, Air Force Surveys in Geophysics, No. 246, 1972.

[2] International Geomagnetic Reference Field 1975, EØS, T.A.G.U. 57, 3, 1976.

hope to distinguish secular change and any change in instrumentation.

2.3 Utility of Geomagnetic Observatory

The value of the magnetic observatory to the scientific community can be judged by requests for use of its data. The magnetic exploration of potential oil and gas resources off the coast of Massachusetts made use of the total field records to remove the daily variation from their data. Aero Survey of Houston is, this summer, using the total field recording in processing a very detailed aeromagnetic survey of northeastern Massachusetts and southern New Hampshire. A team from the U.S. Geological Survey in Denver used the variometer records to confirm events recorded on their temporary network in New York and New England. The Canadian group, which is operating a network in New York and northern New England, is using the Weston variometer records for comparison with their data. AFGL scientists as well as other Air Force contractors have continuously used both total field records and variometer records in their studies of the ionosphere, aurorae and satellite data. And as mentioned above, the World Data Center-A has sufficient requests for Weston's data to justify the microfilming of the entire set of variometer records.

3. Facility for the Testing of Magnetic Instrumentation

Closely allied to the geomagnetic observatory is the Magnetic Test Tower (Figure 1), designed to control the magnetic field over a relatively small volume of space. The design, construction and calibration of the facility is detailed in the Final Report of contract AF(19) (628) 236. The heart of the system is a set of coils in Braunbek configuration and a very well regulated direct current source. Control of the current permits a decrease, increase cancellation or even reversal of the ambient magnetic field. It was originally designed to test the instrumentation packages of the sounding rockets and to calibrate their magnetometers over the full range of the magnetic environment they were to encounter in space. During this contract period we have made some use of the facility, but AFGL scientists, particularly, Bert Schuman have made extensive use of the facility to test satellite magnetometers.

3.1 Repair of a Satellite Boom

On November 2, 1973, Weston Observatory was delegated by the AFGL to oversee repair work on an extendable magnetometer boom for a satellite. The boom was designed to be deployed about 20 feet from the body of the satellite, once it was in position in space. On the boom a magnetometer was mounted. In the process of calibrating the magnetometer, the boom was slightly damaged. The damage was repaired and the satellite, S3-2, was successfully flown on December 4, 1975 and is still returning data.

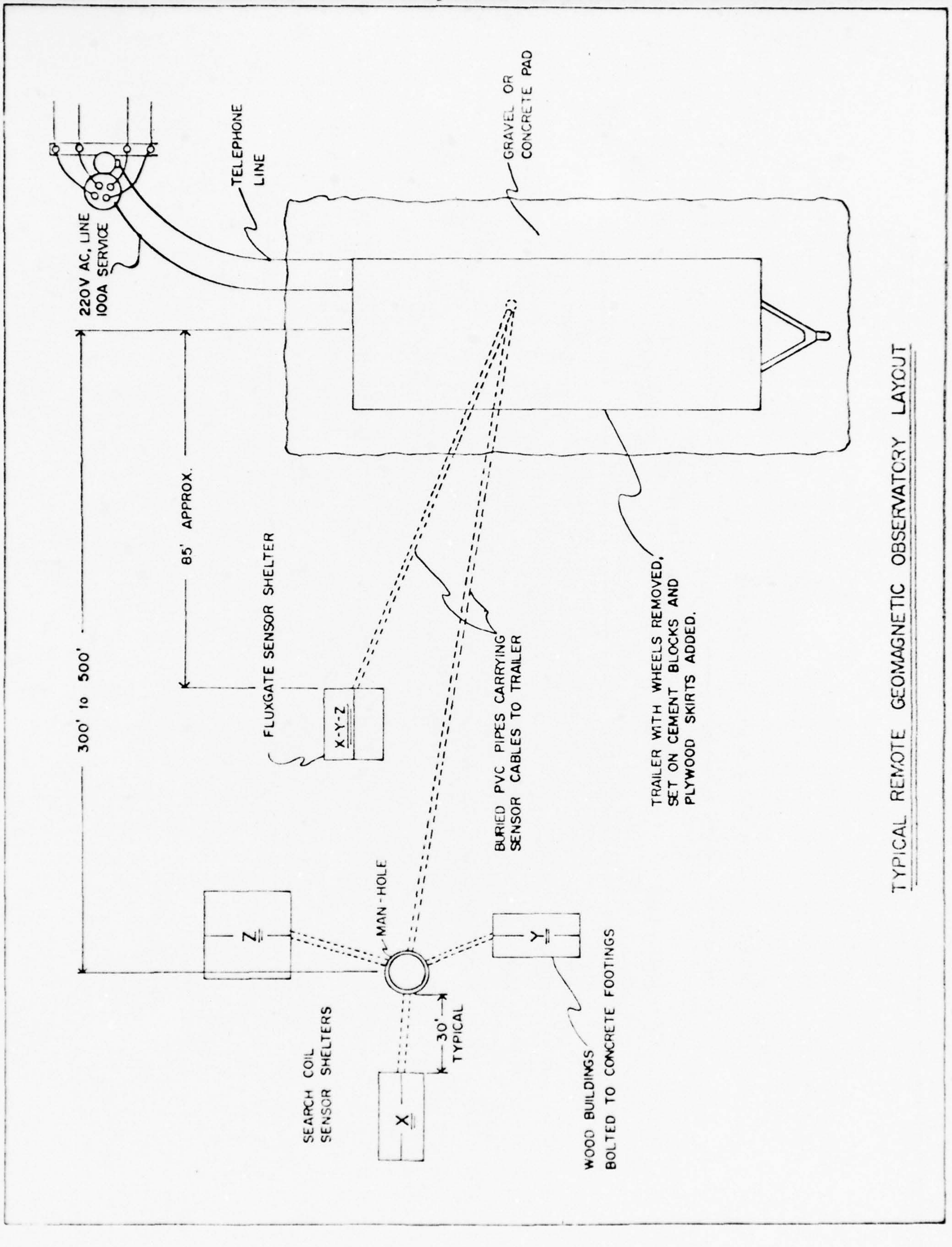
4. Design and Development of an Automatic Magnetic Observatory

In June 1974, a Design and Evaluation Report: Design of an Automatic Observatory Magnetometer was submitted and approved. The problem was to convert the Republic Baseline Magnetometer to a working system which would produce in suitable output form values of the total intensity and of the three orthogonal components of the vector magnetic field at predetermined intervals. The operative elements were a Rubidium total field magnetometer and a set of orthogonal McKeehan coils. By sequentially adding a known magnetic field along each axis of the coils, the vector components of the field can be obtained. The mechanical sequential contactor, which regulates the flow of current to the coils,

TABLE IV Locations of the data collection stations.

Station Name (Post Office)	Corrected Geomagnetic Coordinates N Lat	Corrected Geomagnetic Coordinates E Long	Geographic Coordinates N Lat	Geographic Coordinates W Long	Government Installation
Newport, WA	55.2	299.6	48.3	117.1	USGS Newport Geophysical Observatory
Rapid City, SD	54.1	317.3	44.2	103.1	Ellsworth Air Force Base
Camp Douglas, WI	56.3	334.2	44.0	90.3	Volk Field
Mount Clemens, MI	55.8	344.8	42.6	82.9	Selfridge Air National Guard Base
Sudbury, MA	55.8	1.9	42.2	71.3	Army Natick Laboratory Annex
Lompoc, CA	40.2	300.6	34.7	120.6	Vandenberg Air Force Base
San Antonio, TX	39.5	325.6	29.5	98.3	Brooks Air Force Base
Tampa, FL	40.7	344.9	27.8	82.5	MacDill Air Force Base

Figure 3



220V AC, LINE
100A SERVICE
TELEPHONE LINE
GRAVEL OR CONCRETE PAD
300' to 500'
85' APPROX.
FLUXGATE SENSOR SHELTER
X-Y-Z
BURIED PVC PIPES CARRYING SENSOR CABLES TO TRAILER
TRAILER WITH WHEELS REMOVED, SET ON CEMENT BLOCKS AND PLYWOOD SKIRTS ADDED.
Z
Y
X
MAN-HOLE
30' TYPICAL
SEARCH COIL SENSOR SHELTERS
WOOD BUILDINGS BOLTED TO CONCRETE FOOTINGS
TYPICAL REMOTE GEOMAGNETIC OBSERVATORY LAYOUT

will be replaced by electronic timing circuitry. A new and well-regulated 28 volt power supply and a Hewlett-Packard Data Punch have been purchased. Since Project MAGAF has top priority, the system is not yet operating. There is still work to be done on the control circuits. We have decided on a ten minute data interval for normal operation. When magnetic activity increases, we shall rely on the frequency gate, mentioned above, to increase the recording speed to one minute intervals. The output will be the digital Larmor frequency on punched tape which will be processed at the Boston College computer center. A disadvantage of this type of output is that the quality of the data is not known until after processing. But there is considerable advantage in having the data in digital form.

5. The Magnetometer Network

The Magnetometer Network has been described in an AFGL publication[1]. The principal instruments at each site are a three component fluxgate magnetometer produced by U.C.L.A. and a three component searchcoil magnetometer, a product of Geotronics Inc. Weston Observatory's task was to procure components for the system, test and calibrate the magnetometers, install all components in mobile vans, cooperate with AFGL personnel in the installation at the sites and to assist AFGL personnel in maintaining the system in operation. The location of the existing data collection stations and projected station are listed in Table 4. The Sudbury, Mass. site and Weston Observatory have been used as test sites for instrumentation before installation at the more remote stations. A typical network station is shown in Figure 3.

---

[1] Knecht, D.J., and P.M. Pazich, The AFGL Magnetometer Network, AFGL, Hanscom Air Force Base, MA 1976.

5.1 Instrumentation Vans

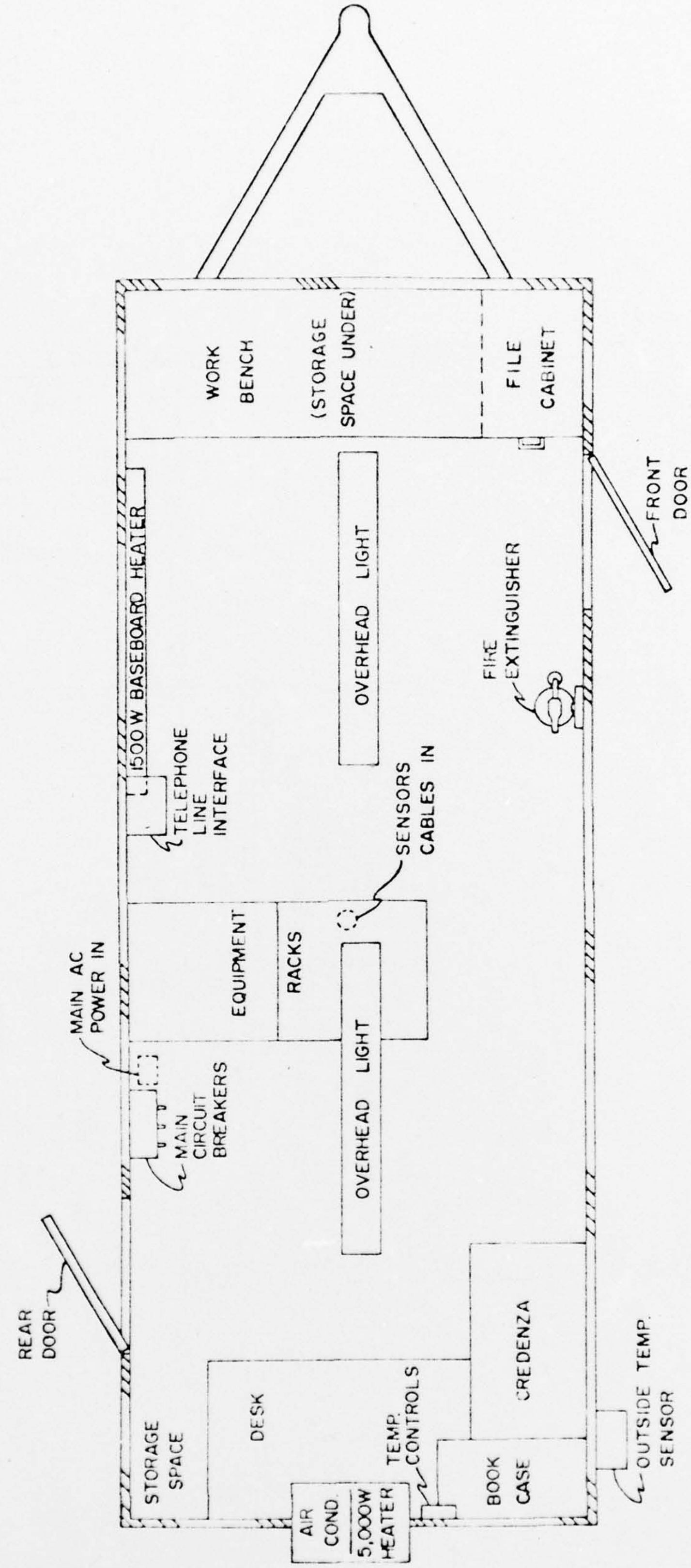
A Design and Specification Report: "Specifications for Micropulsation Trailers" was submitted on November 30, 1973 and after minor modification was approved by AFGL on December 5, 1973. Procurement of materials and equipment began in December 1973.

The mobile instrument shelter is a standard 8' by 20' mobile office van made by Relco Corp., Billerica, Mass. Additions included 4" of fiberglass insulation on all surfaces, 10,000 BTU/hr. cooling and 4,750 watts heating, a work bench and a second door. The temperature control system for the combined air-conditioner-heater and the supplemental baseboard heater was designed to maintain an inside temperature of $70^{\circ}F \pm 10^{\circ}$ against an outside temperature range of -20° to $100^{\circ}F$, allowing a daily inside variation of only $\pm 4^{\circ}F$. Special controls were installed to prevent heating and cooling at the same time and to prevent rapid oscillation of the heat-cool cycle. With all equipment installed and the magnetometers in operation, the inside temperature was recorded during September and October 1974 at Weston. At no time did the inside daily variation of temperature exceed the limit, $\pm 4^{\circ}F$. Typical variations were less than $\pm 2^{\circ}F$. The change from heating to cooling and vice versa was smooth and reliable.

After installation at three sites, the compressors of the air conditioners burned out. The failure was due to the loss of cooling fluid through a defect which developed in a copper-to-aluminum crimp joint. Speculation is that the joint was cracked or weakened during transportation on flatbed trailer trucks. The air conditioners were mounted on the rear walls of the office van. Severe jolting during transit could have affected the junction. In the future, the air conditioning units will be secured to the floor of the van for shipment and installed after transportation.

Figure 4 and 5 give the details of the instrumentation in

Figure 4



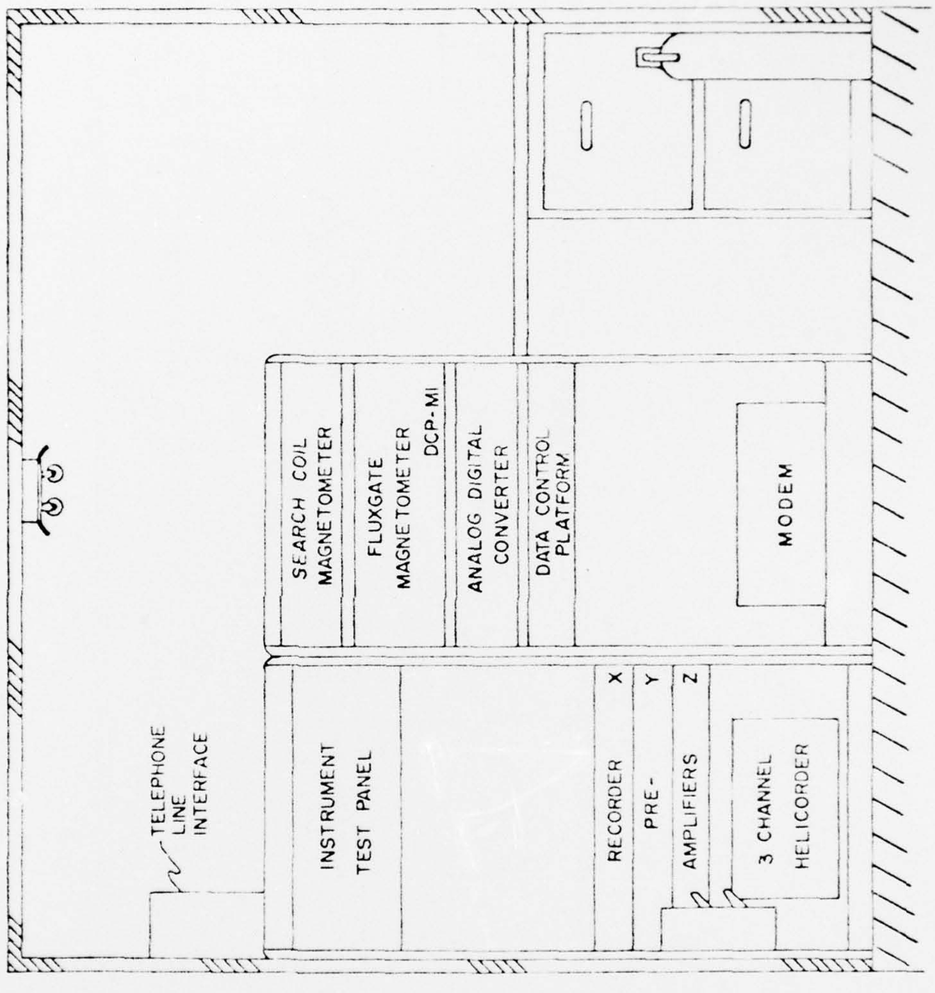
FLOOR PLAN

TYPICAL REMOTE OBSERVATORY INSTRUMENT VAN LAYOUT

Figure 5

VIEW OUTLINING DEVICE LOCATIONS

IN EQUIPMENT RACKS



each trailer. The electronics for the U.C.L.A. fluxgate magnetometers and for the Geotronics induction coil magnetometers are in one rack with the analog to digital converter, the data conditioning unit and the Western Union Modem. The test and recording equipment in the second rack included two Tektronics TM501 power supplies and mainframe, a RG501 ramp generator, a MR501 x-y monitor, a DM501 digital multimeter and a three channel helicorder with amplifiers. A complete list of furnishings and housekeeping equipment is given in Table 5.

In the interests of economy, in the future trailers, the test equipment will not be permanently installed. A Tektronics TM515 mainframe with a SC502 dual trace oscilloscope, a DC503 frequency counter, an FG501 function generator, and a DM501 digital multimeter, all of which are packed in one suitcase, have been purchased and will be carried to the sites.

The vans were painted at Weston with markings as required of buildings on an air base. Due to very high winds encountered in South Dakota, the van was anchored with aircraft cable secured to a concrete pad.

5.2 Housing for the Magnetometers

The shelters for the magnetometers (Figures 6, 7, and 8) were designed by AFGL and were to be procured under separate contracts. The shelters for the Washington site were built commercially. But financial considerations dictated that the others be built at Weston in modular form, assembled, painted, and then broken down for transportation to the sites. The shelters, described by Figures 6, 7, and 8, have been completely satisfactory. For the Florida site, the unusual conditions of heat and very high humidity coupled with the possibility of hurricane winds and rains dictated that special fiberglass units be purchased. Considerable effort went into the procurement of the quartz sand which is free of magnetic material. This sand provides a mounting medium and thermal insulation for the

Furnishings: a desk, file cabinet, bookcase, credenza, a chair with arms, a chair without arms, a stool with a rotating seat, fiberglass foam-backed insulated window curtains, an electric clock, a wastebasket, an interior floor mat, and an exterior floor mat.

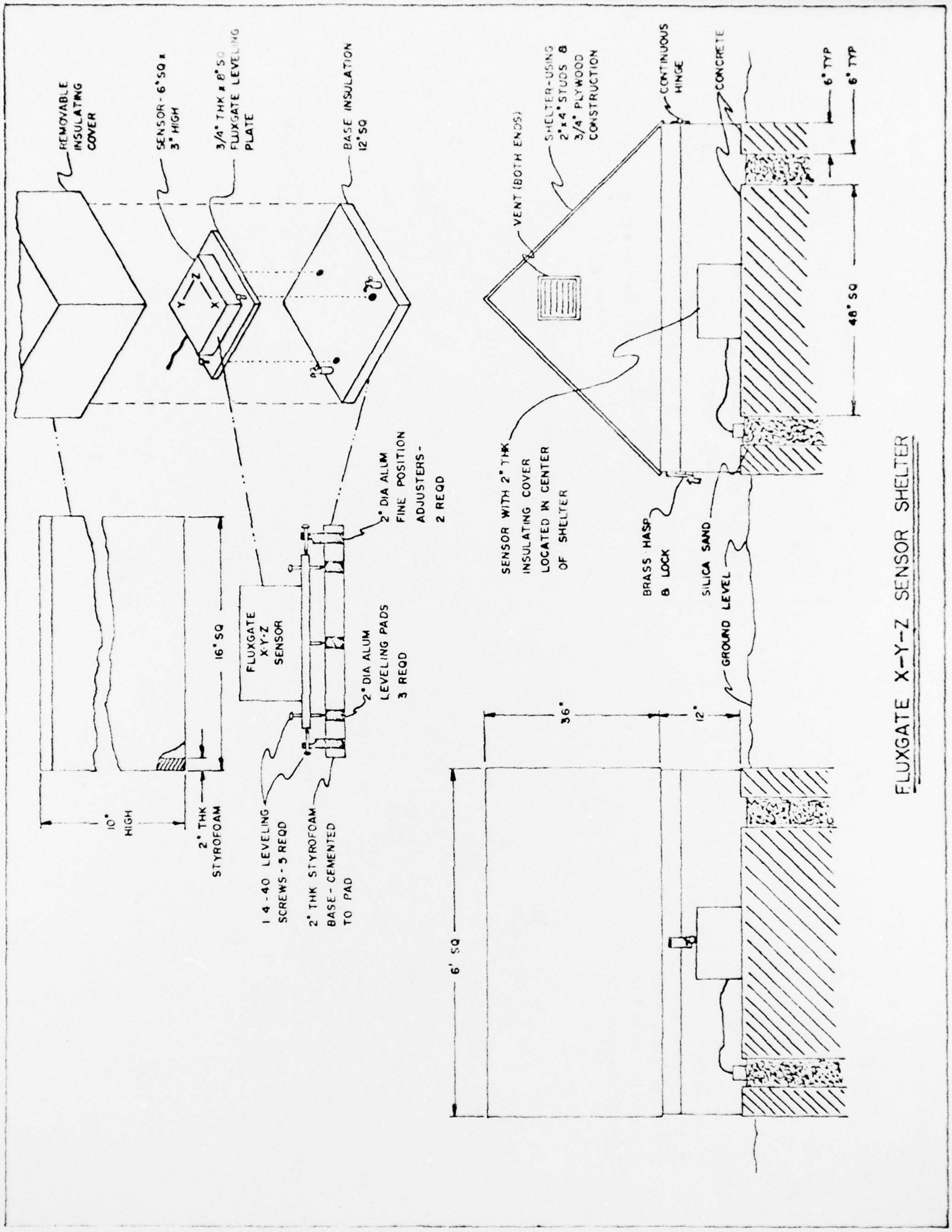
Housekeeping equipment and tools including one of each of the following:

Flashlight	Hammer
Extension light	Saw
First aid kit	Wrecking bar
Snake bite kit	Vise
Dust pan	Ax
Brush	Soldering gun kit with solder
Brrom	Lug wrench
10' wooden ladder	Small volt-ohmeter
Shovel	Assortment of hardware
Fire extinguisher	Assortment of connectors and Leads
Pail	Electrical tape
Sponge	Extra fuses
	Assortment of stationary supplies

Manuals, workbooks and schematic for the magnetometers and test equipment.

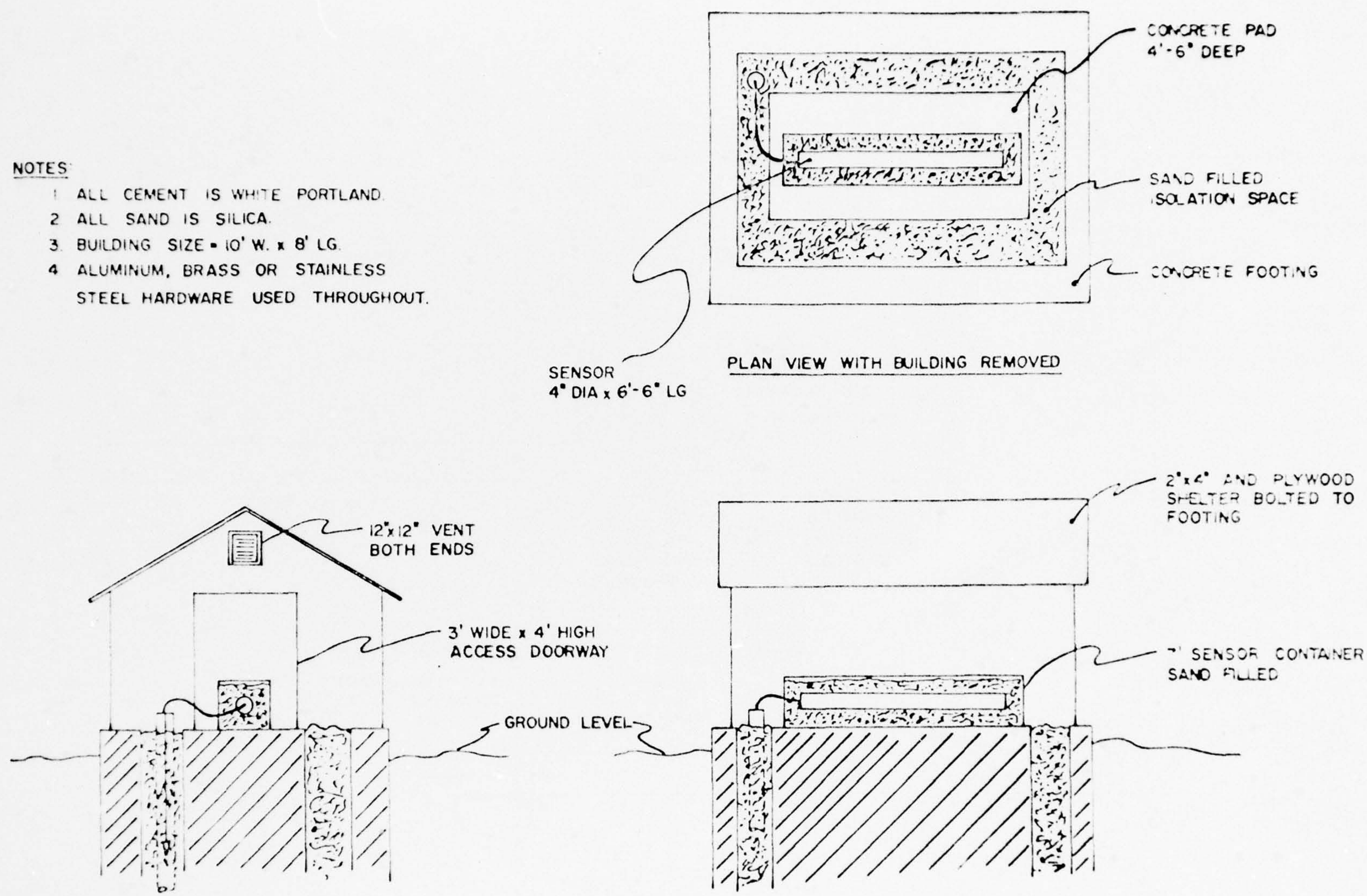
TABLE V

Figure 6



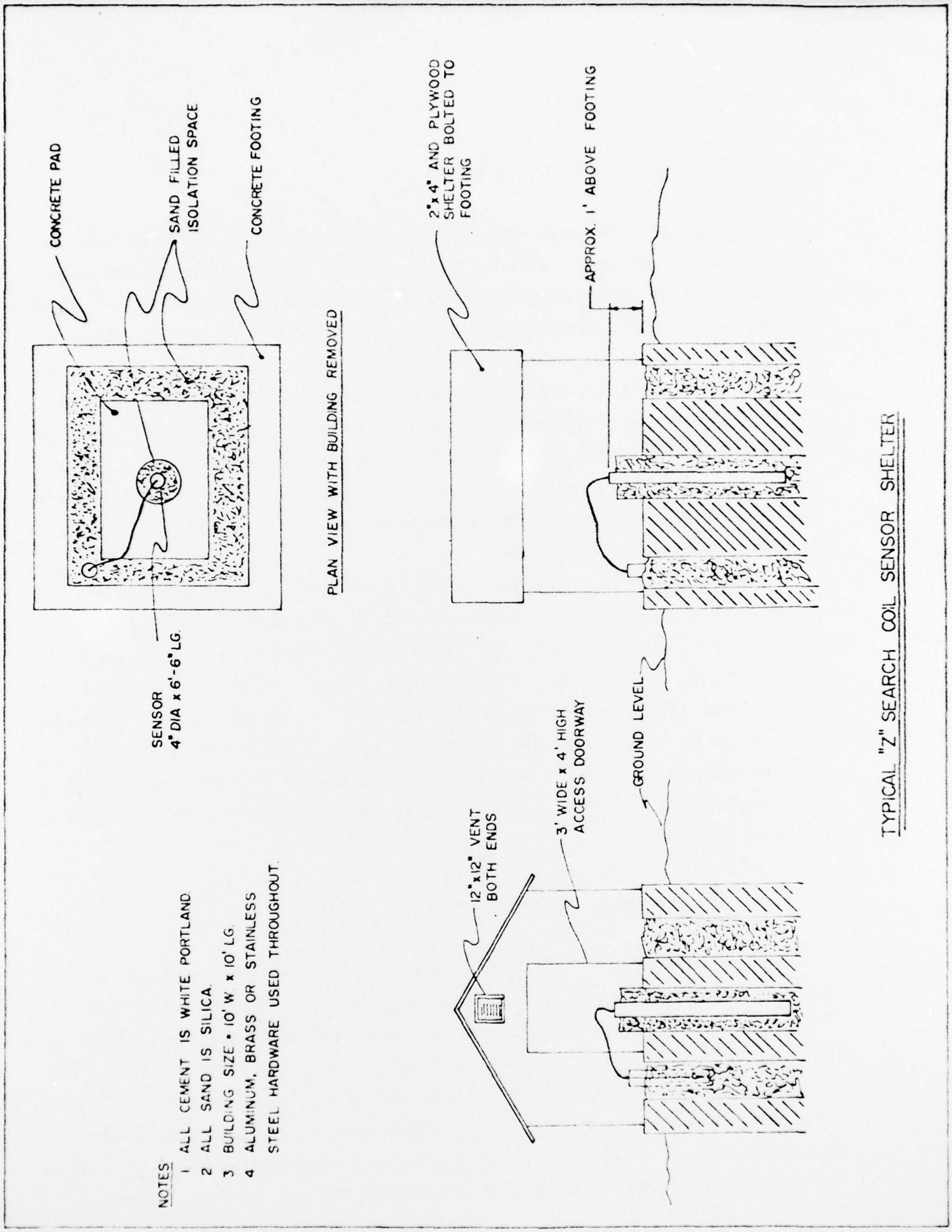
FLUXGATE X-Y-Z SENSOR SHELTER

Figure 7



TYPICAL "X" AND "Y" SEARCH COIL SENSOR SHELTERS

Figure 8



TYPICAL "Z" SEARCH COIL SENSOR SHELTER

search coil sensors.

5.3 The Fluxgate Magnetometer

All magnetometers were run continuously at Weston for at least one month prior to installation. Component values were compared with those obtained from each similar unit, the standard observatory instruments and from Schonstedt HSM-1 magnetometers. Summed component values were then compared with total field readings from a proton precession magnetometer and the alignment of level bubbles with the sensor axes of the x and y sensor were checked. The combined coarse-fine stepping procedure was investigated for overall smoothness and stepping accuracy and for responce effects when observed through the normal fine output filter section.

After installation failures occurred at several sites, usually for different reasons. These included a 5 volt power supply, an intermittant -15 volt power supply, a drift in the y-component and an open sensor cable lead. The drift has been attributed to water seepage in the PVC cable ducts and is being corrected by construction of water tight cable and by above ground conduits. An open cable lead was a direct result of a gnawing rodent. Steps have been taken to prevent recurrence of this action.

5.4 The Searchcoil Magnetometer

The searchcoil magnetometers respond to the rate of change of the magnetic field. A large bar magnet, mounted so that it could be rotated at varying rpm, produced test fields. The frequency response of the amplifiers was found to be flat from 10^{-3} Hertz to 1 Hertz. The drift of the amplifiers was within the manufacturer's value of $\pm$ 2 microvolts referenced to input. The searchcoil magnetometers performed equally well when tested in fields of different basic baseline values in the Weston earth's field cancelling system. During long term testing, simulating actual field conditions, two amplifiers failed, both during thunder storms.

Numerous failures occurred after installation at the sites due to primarily to two causes: 1) potting compound creep in component sockets, and 2) transient induced operational amplifier failures. The urethane compound, used to insulate and mechanically stabilize components leaked into I.C. sockets on almost every printed circuit board, causing intermittant operation or total failure at every site. We found a solvent which would remove the urethane and in most cases restored the magnetometers to operation. But severe cases were returned to the manufacturer, who has changed the manufacturing process in order to eliminate future problems and provide more stability during long term operation.

At several sites the operational amplifier failure seemed to be associated with thunder storms, as had occurred during test runs at Weston, but could hardly be caused directly by lightning strikes, because catastrophic failure would be expected. We borrowed a small laboratory demonstration Van de Graf generator and ran it in proximity to the electronic package. Failure could be induced in one specific component. The failure was due to static discharge breaking down junction material in the operational amplifier. The problem was solved by replacing the amplifier (type ML709A) by a different amplifier (BB3522). The circumstances of the failure were unusual, association with a lightning storm and the fact that identical amplifiers in similar circuitry in the same electronics package were sometimes not affected.

5.5 Additional Sites

Weston personnel assisted in the survey of the geomagnetic environment of the sites in California and Florida. Procurement and installation of the van and fiberglass shelters for the Florida site has been completed.

6. Conclusion

Five of the stations in the proposed network have been installed and are operational. Since Weston personnel are now thoroughly familiar with the instrumentation, the installation of the additional stations should proceed more rapidly. Normal maintenance should be routine since common modes of failure are known. Catastrophe is not unknown. This summer, a lightning discharge, following the telephone cable, entered the van in South Dakota, destroyed the Western Union Modem and caused extensive damage to the searchcoil magnetometer electronics, A to D converter and DCP. The station was quickly restored to operation by installing equipment from the experimental Sudbury site. The renovated equipment will then be installed in Sudbury. Because of the distances separating the stations and Weston, there are inevitable delays in responding to breakdowns. Therefore a significant part of the program of maintenance must be an ever growing knowledge of the system; its strengths, its weaknesses and a continual effort to improve its reliability.

Contract Personnel

Robert Dalrymple	Technician	8-1-73	
Robert E. Somers	Principal Investigator	8-1-73	2-19-74
Todd Li	Data Analyst	8-1-73	6-30-74
J.F. Devane, S.J.	Project Supervisor	2-20-74	
Edward Johnson	Project Scientist	2-25-74	
Rita Comeau	Secretary	8-1-73	6-30-74
Robin Smith	"	7-1-74	2-28-76
Patti Gremillion	"	3-1-76	7-31-76
Janet Reach	"	8-1-76	

Bibliography

Harwood, J.M. and S.R.C. Malin, 1976, Present Trends in the Earth's Magnetic Field, Nature 259, #5543.

Hutchinson, R.O., and J. Pomeroy, S.J., 1961, Weston Magnetic Facility, T.A.G.U. 42, 3.

International Geomagnetic Reference Field 1975, 1976, EØS, T.A.G.U., 57, 3.

Knecht, D.J., The Geomagnetic Field, 1972, Air Force Surveys in Geophysics, No. 246.

Knecht, D.J., and P.M. Pazich, 1976, The AFGL Magnetometer Network, AFGL, Bedford, MA.

Lanzerotti, L.J., R.D. Regan, M., Sigiura, D.J. Williams, 1976 Magnetometer Networks During the International Magnetospheric Study, EØS, T.A.G.U. 57, 6.

Manka, R.N., 1976, U.S. Program for the IMS, EØS, T.A.G.U. 57, 2.

Matsushita, S. and W.H.Campbell, Eds., 1967, Physics of Geomagnetic Phenomena, Academic Press, pp. 321-323.

Roederer, J., 1976, IMS 1976-1979, New Concepts in International Scientific Cooperation EØS, T.A.G.U. 57, 1.

Printed by
United States Air Force
Hanscom AFB, Mass. 01731